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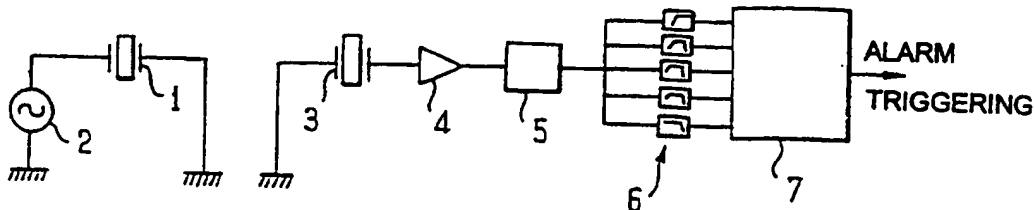
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**GB 2310720 A****GB 2290614 A****GB 2050022 A****EP 0743540 A2****EP 0654768 A1****EP 0646901 A1**

(58) Field of Search

**UK CL (Edition P) G1A AMQX, G1G GPE GPGX, H4D****DRPA DSPV****INT CL<sup>6</sup> B60R 25/10, G08B 13/16 13/18 13/181 13/183****ONLINE: WPI JAPIO**(54) **Vehicle intruder alarm**

(57) A method of detecting intrusion into a vehicle is disclosed which incorporates an ultrasonic wave generator (1, 2) and a detection system that amplifies and rectifies (4, 5) the signal received by a detector (3). The system uses fuzzy logic to analyse various aspects of the detected signal, such as its frequency content (using filters 6), power and duration, so as to detect variations in this signal. The fuzzy logic output, whose functionality is implemented using a microprocessor (7), may then be used to trigger an alarm. The advantages are that by using fuzzy logic the number of false alarms may be reduced, and that by using a microprocessor to implement the fuzzy logic the conditions which trigger the alarm may be altered without changing the hardware.

**FIG. 4****GB 2 319 842 A**

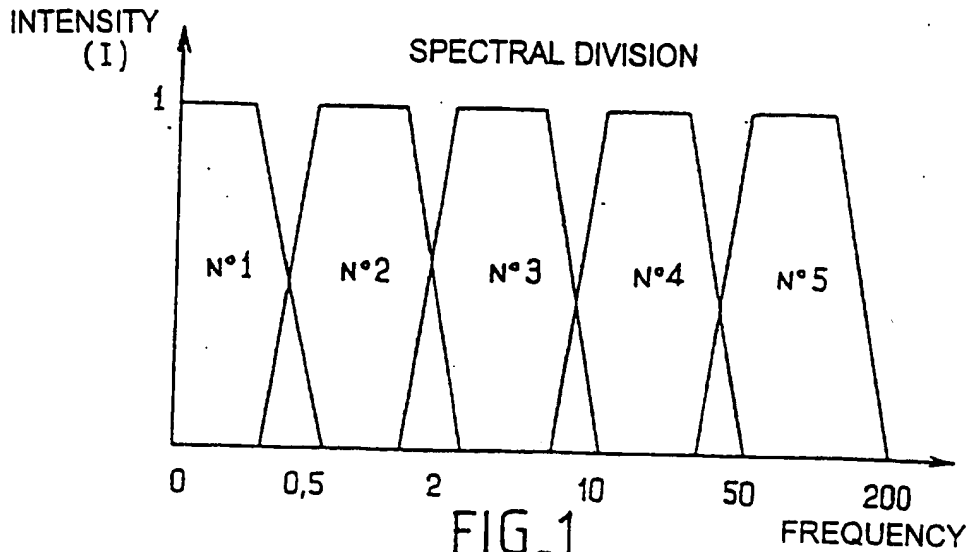


FIG.1

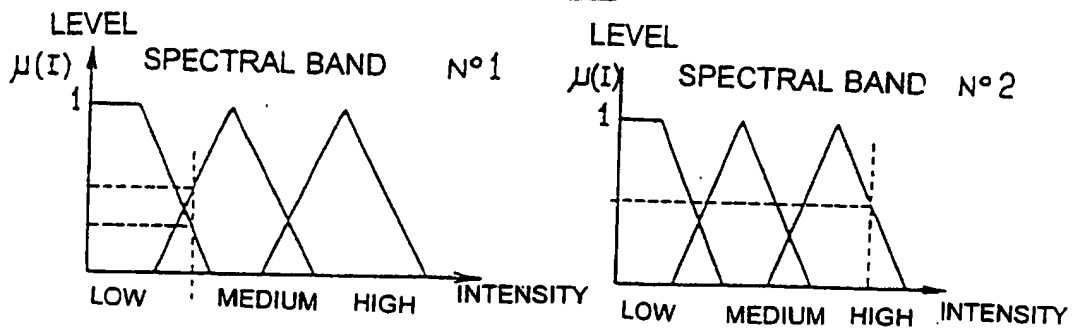


FIG.2

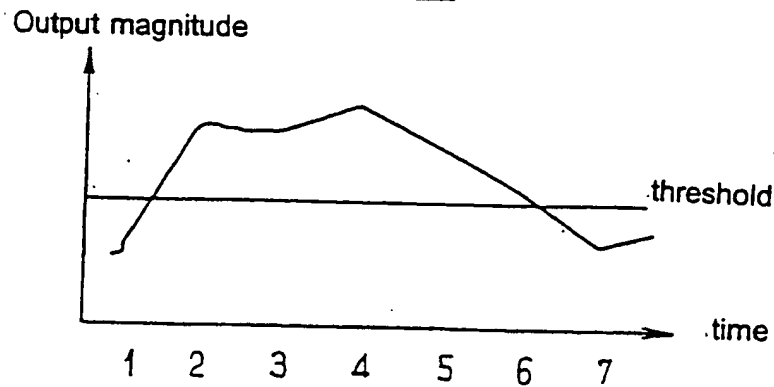


FIG.3

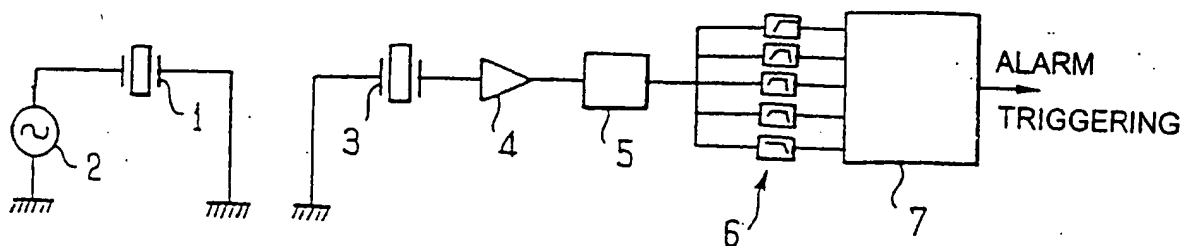


FIG.4

METHOD AND DEVICE FOR DETECTING INTRUSION  
INTO A MOTOR VEHICLE

The present invention relates to the detection of intrusion into a motor vehicle.

More particularly, it concerns methods and devices for detecting intrusion by emitting and receiving waves, notably of ultrasonic type.

Detections of this type are usually difficult to perfect and generally are the subject of compromise between detection sensitivity and immunity with regard to events capable of triggering false alarms.

There the vehicle is the centre of a wave field, a combination of the waves emitted and reflected in the vehicle, which is stationary if the environment is entirely still or almost stationary if for example the environment is subject to slight variations in temperature.

Conventionally a movement is detected by demodulating the amplitude or phase of the ultrasonic wave received at the receiver and analysing the received wave according to several cumulative criteria, such as the amplitude, duration and frequency of the detected signal.

For example, it may be decided that an intrusion is characterised by a signal level above a given threshold in the 5 to 50 Hz frequency band for a duration greater than 0.6 seconds.

However, these decision rules are generally not entirely satisfactory, given that they correspond to a compromise between different possible situations.

The risks of false alarms in the presence of an event or a new environment

(particular vibration of the vehicle, unanticipated seat position, etc) remain significant.

One aim of the invention is to propose an intrusion detection which may have good results in terms of sensitivity and with which the risk of false alarms may be further reduced, preferably to become almost zero.

According to one aspect of the present invention there is provided a method of detecting intrusion into a motor vehicle by emitting and receiving waves, notably ultrasonic waves, wherein the values of a number of given parameters are determined on the received signals, and in that fuzzy logic processing is applied to these parameters in order to determine one (or more) output magnitude or magnitudes from which the triggering or not of the alarm is decided.

It may be recalled that fuzzy logic theory makes it possible to express the greater or lesser membership of a given state from membership functions which associate, with a value of a given parameter, a value representing the degree of membership of that state.

Fuzzy logic processing consists of determining, from the parameter values which are available, values of degrees of membership of different states, of applying, to these degrees of membership values, inference rules making it possible to determine values of degrees of membership of other states, and then of determining, according to the degrees of membership values thus obtained, the value of one or more output parameters.

For a more detailed presentation of fuzzy logic theory, and examples of its applications, the following various publications may advantageously be referred to:

- "Intelligence unmasked or fuzzy logic", Claire Remy, *Microsystèmes*, May 1986,
- "Artificial Intelligence - Fuzzy Logic", Jean-François Peyrucat, *Mesures*, October 1994,
- "Fuzzy Logic in Control Systems, Fuzzy Logic Controller, Part I" and "Fuzzy Logic in Control Systems, Fuzzy Logic Controller, Part II", Chuen Chien Lee, in IEEE Transactions on Systems, Man and Cybernetics, Vol 20, May-April 1990,
- "Fuzzy Control Theory: a non-linear case", Hao Ying, William Siler and James J. Buckley, in Automatica Vol 26, No. 3, 1990.

According to the second aspect of the invention there is provided a device having means for emitting and receiving a signal, means for determining different parameters on the received signal, and means for implementing fuzzy logic processing on these input parameters and controlling possible triggering of the alarm according to the parameter or parameters determined at the output of this processing.

Other characteristics and advantages of the invention will emerge further from the description which follows. This description is purely illustrative and non-limiting. It must be read with reference to the accompanying drawings in which:

- Figure 1 illustrates a spectral splitting which is carried out in one possible embodiment of the invention;
- Figure 2 illustrates one possible form for the functions of membership of different linguistic values of two spectral bands of the split of Figure 1;

- Figure 3 is a graph which shows the change, as a function of time, of the magnitude at the output of a processing in accordance with one possible embodiment of the invention; and
- Figure 4 is a block diagram of a device in accordance with one possible embodiment of the invention.

The intrusion detection illustrated in Figures 1 to 3 implements, on the (phase or amplitude) demodulated signal, a splitting of the signal into a number of successive frequency bands of the same width between 0 and 200 Hz, corresponding for example to the filterings 1 to 5 illustrated in Figure 1.

Spectral analysis of the events to which a vehicle may be subjected, notably noises (wind, infrared, thermal gradient), impacts (windows, wheels, bodywork), and intrusions (slow or fast), show that it is possible to characterise each of these events by their level of intensity in each of these spectral bands.

Thus an impact is characterised by the presence of signal peaks around 20 Hz.

Then again, the typical spectrum of an intrusion is a wide spectrum distributed between 10 and 60 Hz.

Fuzzy logic processing is implemented on the values of signal intensity in each of these frequency bands.

To that end, three linguistic values such as "low", "medium" and "high" are for example assigned to each frequency band, corresponding, according to the intensity  $I$  of the signal in this band, to membership functions as

illustrated in Figure 2 for bands 1 and 2.

It should be stated that, in fuzzy logic, a membership function is a function which gives a value ( $\mu(I)$ ) expressing the degree of membership, of the event, of the state which corresponds to the linguistic value associated with it.

As may be seen in Figure 2, these functions express the continuity between two successive states: when the intensity  $I$  of the signal varies in a given spectral band, the signal passes progressively from a state where it is considered to be "low", to a state where it is considered to be "medium", then to a state where it is considered to be "high".

Once the degrees  $\mu(I)$  of membership of the different states which correspond to the three aforementioned linguistic values have been determined for each spectral band 1 to 5 (the so-called "fuzzification" step), inference rules making it possible to determine whether or not an alarm is to be triggered are applied to the values thus obtained.

It should be stated that the inference rules are operators applied to the degrees  $\mu(I)$  of membership of the different states corresponding to the linguistic input values, in order to determine the degree or degrees of membership of a state corresponding to a linguistic output value.

The conjunctive and disjunctive operators

A AND B, THEN C, and  
A OR B THEN C,

principally used are the Zadeh operators, which are mathematically written respectively:

$$\mu_C = \min (\mu_A, \mu_B) \text{ and}$$

$$\mu_C = \max (\mu_A, \mu_B),$$

where  $\mu_A$ ,  $\mu_B$  and  $\mu_C$  are the degrees of membership of the states A, B and C.

Other operators may of course be used, notably the Mamdani or Larsen operators or those of Lukasiewicz which are written:

$$\mu_{A \text{ AND } B} = \max (0, \mu_A + \mu_B - 1) \text{ and}$$

$$\mu_{A \text{ OR } B} = \min (1, \mu_A + \mu_B).$$

In the example illustrated in Figures 1 to 3, the inference rules used may be the following.

If the level in band 1 is high and the level in bands 2 and 3 is low THEN the level of the ALARM TRIGGER output is "low" (thermal noise case), which is expressed for example mathematically by:

$$\mu^1_{\text{LOW ALARM TRIGGER}}$$

$$= \min (\mu_{\text{HIGH BAND 1}}, \mu_{\text{LOW BAND 2}}, \mu_{\text{LOW BAND 3}})$$

If the level in band 1 is low and the level in bands 2 and 3 is high THEN the level of the ALARM TRIGGER output is "high" (intrusion case), which is expressed for example mathematically by:

$$\mu_{\text{HIGH ALARM TRIGGER}}$$

$$= \min (\mu_{\text{LOW BAND 1}}, \mu_{\text{HIGH BAND 2}}, \mu_{\text{HIGH BAND 3}})$$

If the level in band 1 is low, the level in band 2 is high and the level in band 3 is low THEN the level of the ALARM TRIGGER output will be low (vibration case), which is expressed for example mathematically by:

$$\mu^2_{\text{LOW ALARM TRIGGER}} = \min (\mu_{\text{LOW BAND 1}}, \mu_{\text{HIGH BAND 2}}, \mu_{\text{LOW BAND 3}})$$

Thus, for a given input configuration, for each inference rule, an output value is available from which it is possible to calculate, since the output membership function is known, the value of the parameter which an attempt is being made to determine (in this case, an alarm triggering level). According to the terminology generally used in fuzzy logic, this processing step is designated by "defuzzification".

The alarm triggering decision is next taken according to the different alarm triggering levels calculated for each inference rule.

For example, these different levels are weighted in order to calculate a barycentric value.

The output magnitude thus obtained is compared with a threshold for triggering the alarm.

Advantageously, in order to take into account the changing character of events, calculation of the output magnitude is repeated regularly and smoothing is carried out on the sampling thus obtained. The sampling time is advantageously between 0.01 and 0.2 seconds.

Figure 4 illustrates one possible embodiment for a device in accordance with the invention.

This device has an ultrasonic emitter 1 connected at the input to an oscillator 2 for continuous generation of an amplitude modulated signal.

It also has an ultrasonic sensor 3 mounted in series with an amplifier 4, means 5 of amplitude demodulation by rectification, and filtering means 6, which define a low-pass filter for band 1, three band-pass filters for bands 2 to 4, and a high-pass or band-pass filter for band 5 - a band-pass filter being preferable in order to cut off all the high frequencies which might prejudice the processing.

The signals leaving these filtering means 6 are sampled and converted digitally at the input of a microprocessor 7, which implements the "fuzzification", inference and "defuzzification" processing as well as digital smoothing of the output magnitudes obtained, and then a comparison of these magnitudes with a threshold value.

Of course, types of inference rule other than those which have just been described above may be applied, since they are sufficient in number to answer the problems with the required accuracy. Notably, inference rules on bands 4 and 5 may also be used to eliminate certain marginal perturbations.

Also, the inference rules may be determined automatically by neuromimetic calculation from files of experimental measurements representing all conceivable situations.

It is therefore to be noted that the system is highly flexible, since the file of inference rules can be added to at any instant by a supplementary file, which makes it possible to correct any deficiency without having to modify the system architecture.

Also, input variables other than the intensity of the signal in certain frequency bands may also be used.

In particular, in combination with one or more parameters relating to the signal frequency, the mean power of the modulated signal, which characterises the amplitude of the event, may be used.

Thus the input parameters of the fuzzy logic processing may be constituted by the signal intensities determined by the frequency bands 1 to 5, and by the mean power of the modulated signal.

As a further variant, a parameter relating to the signal frequency may be the number of times the modulated signal goes to 0, which characterises the frequency of the signal when the latter is centred on 0, or the number of times its derivative goes to 0, which characterises the frequency of the said signal when the latter is not correctly centred on 0.

These two parameters may be used as input parameters for the processing, independently of one another or together, in combination with the mean power of the demodulated signal.

CLAIMS

1. A method of detecting intrusion into a motor vehicle by emitting and receiving waves, notably ultrasonic waves, wherein the values of a number of given parameters are determined on the received signals, and in that fuzzy logic processing is applied to these parameters in order to determine one (or more) output magnitude or magnitudes from which the triggering or not of the alarm is decided.
2. A method according to Claim 1, characterised in that determination of this or these output parameter or parameters is repeated regularly, and in that smoothing is carried out on the sampling thus obtained.
3. A method according to Claim 2, characterised in that the sampling time is between 0.01 and 0.2 seconds.
4. A method according to any of the preceding claims, characterised in that an output magnitude is an alarm triggering level, and in that this triggering level is compared with a predetermined triggering threshold.
5. A method according to any of the preceding claims, characterised in that at least one input parameter is a parameter related to the signal frequency.
6. A method according to Claim 5, characterised in that another input parameter is the power of the demodulated signal.
7. A method according to either of Claims 5 or 6, characterised in that the received signal is filtered in order to determine the intensity of this signal in different frequency bands, and in that the signal intensities thus determined for these different bands are used as input parameters of the fuzzy logic processing.

8. A method according to Claim 7, characterised in that the frequency bands are five in number distributed between 0 and 200 Hz and are substantially of the same bandwidth.

9. A device for implementing the method according to any of the preceding claims, having means for emitting (1, 2) and receiving (3) a signal, means (5, 6) for determining different parameters on the received signal, and means (7) for implementing fuzzy logic processing on these input parameters and controlling possible triggering of the alarm according to the parameter or parameters determined at the output of this processing.

10. A method for detecting intrusion into a motor vehicle substantially as herein described with reference to the accompanying drawings.

11. A device for detecting intrusion into a motor vehicle substantially as herein described with reference to the accompanying drawings.

**Amendments to the claims have been filed as follows**

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**CLAIMS**

1. A method of detecting intrusion into a motor vehicle by emitting and receiving waves, wherein the emitted and received waves are ultrasonic waves and wherein the values of a number of given parameters are determined on the received signal, and wherein a fuzzy logic processing is applied to those parameters in order to determine one or more output magnitude(s) from which the triggering or not of an alarm is decided.
2. A method of detecting intrusion into a motor vehicle by emitting and receiving waves, wherein the emitted and received waves are ultrasonic waves and wherein the received signal is filtered in order to determine the intensity of the signal in different frequency bands and wherein the signal intensities thus determined for those different bands are used as input parameters of the fuzzy logic processing in order to determine one or more output magnitude(s) from which the triggering or not of the alarm is determined.
3. A method according to claim 1 or 2, wherein the determination of the output parameter(s) is repeated regularly and in that smoothing is carried out on the sampling thus obtained.
4. A method according to claim 3, wherein the sampling time is between 0.01 and 0.2 seconds.
5. A method according to any preceding claim, wherein the output magnitude is an alarm triggering level, and in that this triggering level is compared with a predetermined triggering threshold.
6. A method according to claim 1, wherein at least one input parameter is a parameter related to the signal frequency.

7. A method according to claim 2 or 6, wherein another input parameter is the power of the demodulated signal.
8. A method according to claim 2, wherein the frequency bands are five in number distributed between 0 and 200 Hz and are substantially of the same bandwidth.
9. A device for implementing the method of detecting intrusion into a motor vehicle according to any of the preceding claims, having means for emitting and receiving an ultrasonic signal, means for determining different parameters on the received signal and means for implementing fuzzy logic processing on these input parameters and controlling possible triggering of the alarm according to the parameter or parameters determined at the output of this processing.
10. A method for detecting intrusion into a motor vehicle substantially as herein described with reference to the accompanying drawings.
11. A device for detecting intrusion into a motor vehicle substantially as herein described with reference to the accompanying drawings.